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AIR PARTICULATES NO. 1

Study Number 22

Report of a Study Conducted by the

ANALYTICAL REFERENCE SERVICE

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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1965

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FOREWORD

The Analytical Reference Service is conducted by the Environmental Health Sciences & Engineering Training Program of the Robert A. Taft Sanitary Engineering Center for the evaluation of laboratory methods in the environmental field. Cooperative studies by member organizations, through analysis of identical samples and critical review of methodology, provide the mechanism for:

> Evaluation of analytical procedures, including precision and accuracy, by comparison of the procedures and results reported by participating laboratories.
>
> Exchange of information regarding method characteristics.
>
> Improvement or replacement of existing methods by development of more accurate procedures, and development of new methodology for determination of new pollutional compounds.

Samples are designed to contain measured amounts of selected constituents. Decisions as to qualitative makeup are made by the ARS staff, the membership, and consultants. Notice of each study is sent to the entire membership.

A portion of the study sample with accompanying data forms for reporting numerical values, a critique of the procedures used, comments on modifications, sources of error, difficulties encountered, or other pertinent factors is then shipped to each of those who express a desire to participate. The results and comments of each study are compiled and a report is prepared.

Initially directed toward examination of water, studies now include air, milk, and food. Some studies are periodically repeated for the advantage of new members to evaluate new methods or to reevaluate existing methods.

The selection of studies is guided by the responses to questionnaires periodically circulated among the membership, which now includes 201 Federal, state, and municipal agencies; industries; universities; consulting firms; and foreign agencies.

James P. Sheehy
Director, Training Program

STUDIES WITH COMPLETED REPORTS

Water-Minerals	Calcium, magnesium, hardness, sulfate, chloride, alkalinity, nitrite, nitrate, sodium, and potassium. Studies completed in 1956, 1958, and 1961.
Water-Metals	Lead, copper, cadmium, aluminum, chromium, iron, manganese, and zinc. Studies completed in 1957 and 1962.
Water-Fluoride	Fluoride in the presence and absence of interferences, with and without distillation with the use of a specified procedures. Studies completed in 1958 and 1961.
Water-Radioactivity	Gross beta activity. Studies completed in 1959, and 1961. Gross beta and strontium-90 activity. Study completed in 1963.
Water-Surfactant	Surfactant in various waters. Studies completed in 1959 and 1963.
Water-Oxygen Demand	Biochemical oxygen demand and chemical oxygen demand. Studies completed in 1960. Chemical oxygen demand. Study completed in 1965.
Water-Trace Elements	Arsenic, boron, selenium, and beryllium. Study completed in 1962.
Freshwater Plankton	Evaluation of the precision and accuracy obtainable by the use of various methods of plankton counting and identification. Study completed in 1964.
Air-Inorganics	Chloride, sulfate, fluoride, and nitrate in aqueous solution and on glass fiber hi-vol filter mats. Study completed in 1958.
Air-Lead	Filter paper tape impregnated with lead. Study completed in 1961.
Air-Sulfur Dioxide	Sulfur dioxide in air with the use of a specified method. Study completed in 1963.
Milk-DDT Residue	DDT in milk. Study completed in 1962.

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ABSTRACT

In this study, 35 participants each analyzed 10 slides of selected air particulates permanently mounted in a solid plasticizer. Slides 1 through 7 contained a single particulate, while slides 8 and 9 contained three each, and slide 10 contained 9 particulates.

Of 770 possible correct identifications that could be made by the 35 participants analyzing the 10 slides, 247 correct identifications were made. Among the participants identifying these particulates, those using a polarizing microscope and a range of magnifications did better than those not doing so. Whereas most of the participants did reasonably well in estimating the size of the particulate on slide number 2, most did very poorly in estimating the percent by weight of each component on slides 8, 9 and 10.

Although no text or standard method on identification of atmospheric particulates exists, the overall results of this study were very good.

AIR PARTICULATES NUMBER 1

PURPOSE OF THE STUDY

The purpose of this study was to gather information on the ability of individual microscopists to determine the identities and/or sources of some common atmospheric particulates.

This report furnishes the participants in this study, as well as other readers, information as to the identities of the samples used. The particulates on each slide are described, and some of the most frequently given incorrect answers are discussed. This report should be of value not only for the data contained herein, but as a reference for future microscopic studies of dust.

DESIGN OF THE STUDY

The particulates used in this study were selected to be representative of particles commonly found in the ambient atmosphere. The participants were informed that slides 1 through 7 were one component and 8 through 10 were mixtures and that all particulates on the slides were selected from the following:

Cotton	Styrofoam	Catalyst dust
Quartz	Mineral wool	Paint spray
Cement	Coniferous wood	Ragweed pollen
Oil soot	Fluorite	Tobacco dust
Incinerator ash	Orlon	Cork dust
Wheat starch	Nylon	Nonconiferous wood
Wood flour	Graphite	Straw
Power-plant fly ash	Domestic-stoker ash	Fertilizer dust
Gypsum	Ground glass	Zinc shot
Fiber glass	Potato starch	Talc
Wool	Rabbit hair	Sodium chloride
Metal dust	Mica	Limestone

A staff member of McCrone Research Institute, Chicago, Illinois prepared all the slides; slides of each particulate were made before slides for the next particulate were made. Although care was taken to minimize contamination by unwanted particles, some foreign particles that might have appeared should not have been of sufficient quantity to affect the results of the examination. Because the number of particulates on slides number 8, 9, and 10 was more than one, the possibility of contamination was greater. For these three slides, exact quantities of each component

were successively weighed on a microbalance until the desired number of particles had been reached. A total of only a few milligrams of each of the three mixtures was prepared in this way, and slides 8, 9, and 10 were made up from these respective bulk mixtures.

In all cases, the mounts were prepared by placing a small portion of the particulate on a slide, adding a few pieces of Aroclor 5460 (a solid plasticizer having a refractive index of 1.66), covering with a coverslip, and warming slightly. The mounting medium melts, spreads, and solidifies, giving a permanent preparation. In some cases, if the cooling was too rapid, the cement cracked and gave an overall spider-web appearance to the preparation. Study participants were informed that this could be corrected by warming slightly and allowing the slide to cool slowly. The slides were then enclosed in cardboard mailers designed for this purpose, sealed with tape, and mailed in padded envelopes to each of the participants in the study.

Each slide was intended to contain the particulates indicated in Table 1.

Table 1. INTENDED COMPOSITION OF SLIDES

Slide No.	Identification
1	Power-plant fly ash
2	Limestone
3	Wood flour
4	Talc
5	Cement
6	Incinerator ash
7	Oil soot
8	Orlon, cotton, and mineral wool
9	Wheat starch, wood flour, and quartz
10	Gypsum, wool, talc, fluorite, graphite power-plant fly ash, metal dust, oil soot, styrofoam[a], domestic-stoker ash

[a] Supposedly added, but not found by referees

On slide 2, the participants were also asked to estimate the average particle size and the size range in microns. The limestone used on slide 2 was obtained from a sieve-sample of 325 mesh or less particles. Theoretically, therefore, all particles should have been of such dimension that they would pass through a 44-micron-square sieve hole.

On slides 8, 9, and 10 the participants were asked to estimate the percent by weight of each particle. The intended percent compositions of these slides is given in Table 2.

Table 2. INTENDED PERCENT COMPOSITION OF SLIDES 8, 9, AND 10

Slide No.	Particle type	Perceht by weight
8	Orlon	25
	Cotton	25
	Mineral wool	50
9	Wood flour	49
	Quartz	49
	Wheat starch	2
10	Gypsum	10
	Wool	10
	Talc	10
	Fluorite	10
	Power-plant fly ash	10
	Metal dust	10
	Oil soot	10
	Graphite	10
	Styrofoam	10
	Domestic-stoker ash	10

REFEREES AND REFEREE ANALYSES

Dr. W.C. McCrone, Jr., McCrone Research Institute, Chicago, Illinois, and J.S. Ferguson, Air Pollution Training, Robert A. Taft Sanitary Engineering Center, served as referees for this study.

Before the slides were mailed out to the participants, 25 of the 58 sets mailed to prospective participants were examined to insure uniformity of sample sets and to establish the true makeup of the slides. (Responses were received from 35 participants.) Both referees used a Zeiss, Jr. polarizing microscope with an eyepiece micrometer for measuring and counting the particles. Martin's diameter[1] was used in size estimation. Weight percentages were obtained by examining the slides, noting the particulates and their relative densities, and finally, estimating the relative weight percentages of the particles contained on the slides.

The results of the referees are given in Table 3.

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Table 3. RESULTS OF REFEREES ANALYSES OF SLIDES

Slide No.	Particle identified	Particle size range	Particle size average	Estimated percent by weight
1	Power-plant fly ash			---
2	Limestone	0.3 - 40μ	4μ	---
3	Wood flour			---
4	Talc			---
5	Cement			---
6	Incinerator ash			---
7	Oil soot			---
8	Orlon			25
	Cotton			25
	Mineral wool			50
9	Wood flour			50
	Quartz			50
	Wheat starch			Trace
10	Gypsum			10[a]
	Wool			10
	Talc			10
	Fluorite			10
	Graphite			10
	Power-plant fly ash			10
	Metal dust			10
	Oil soot			10
	Styrofoam			0
	Domestic-stoker ash			10

[a] Since estimations are generally made to the nearest 5 percent, percentages for slide 10 add up to 90. Even though referees found equal amounts of components, estimates within 1 percent are not practical.

DISCUSSION

HIGHLIGHTS OF THE STUDY

Since a study of this exact nature has not been conducted before, there was no established pattern to follow and no previous work with which to compare results. The results themselves varied greatly; for example, 66 percent of the participants identified wood flour correctly, whereas only 14 percent could identify cement. Throughout the study, those particles that were found to be identifiable by their morphology alone were easier to recognize than those that required knowledge of optical properties, refractive index or other study.

No one identified all the components on the three multicomponent slides correctly. Identification of a single-particle type in mixtures obviously becomes more difficult as the number of components increases.

The use of the polarizing microscope proved to be a definite aid in correct identification. The best success was attained with the use of a wide range of magnification rather than low or high magnification alone.

IDENTIFICATION OF PARTICULATES

The correct identifications of the unknown or unknowns on each slide and the incorrect identifications that comprised a high percentage of reported answers will be discussed for each slide. The participants were given a list of 36 possible particles from which to choose and in some cases the number of incorrect identifications approached this limit. The figures related to the following discussion contain a photomicrograph of each slide and a bar graph which indicates the participant response on each slide.

Slide 1, Figure 1

This slide consisted of fly ash from a large power plant such as a municipal electrical generating station. In many of our larger cities, low-grade coal is ground to a 200-mesh size and sprayed into the combustion chamber of a furnace. If complete combustion occurred, no carbon would be present in the sample, and the particles would be small, clear, glassy spheres in a wide variety of colors. Normally, however, combustion of the fuel is not complete, and these particles will vary in size: some are large, irregular, gray masses and others are spheres with many air bubbles trapped inside. Fe_3O_4, magnetite, a black porous magnetic particle, usually spherical, is found in fly ash from pulverized-coal boilers. Forty-six percent

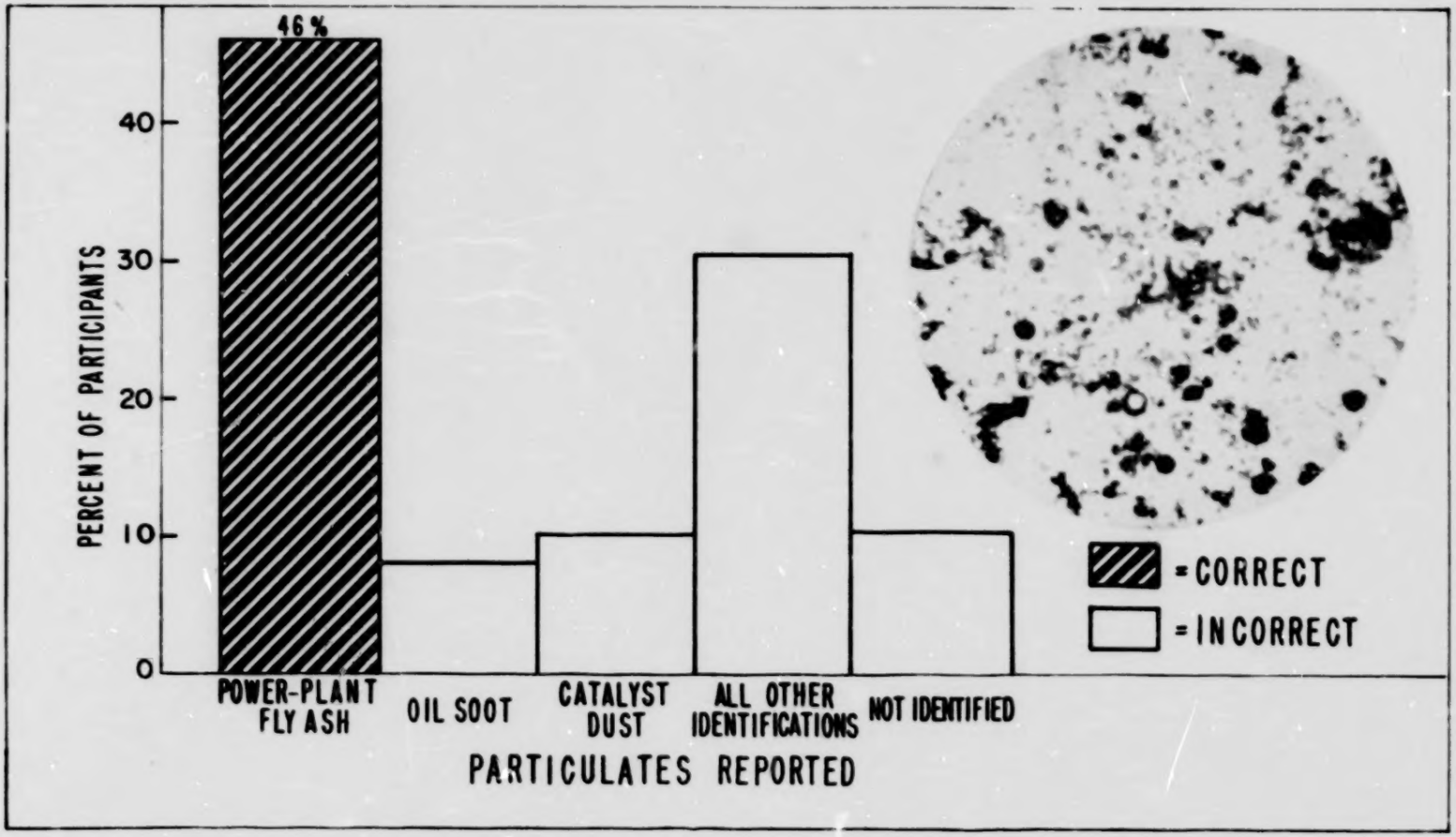

Figure 1. Responses for slide number 1.

of the participants identified this slide correctly. The other two particulates mentioned most frequently as possible answers were oil soot and catalyst dust. The appearance of oil soot is described under slide 7.

Catalyst-dust particles are, in general, much larger than those found and many of the spheres or globular particles are black or dark brown.

Slide 2, Figure 2

In this sample of limestone, the particles were quite small; they were highly birefringent and showed high-order white under crossed polars. Typically, limestone particles will show definite crystalline cleavage.

Seventeen percent identified this slide correctly. Other particles mentioned were quartz and cement. Quartz would show conchoidal fracture rather than cleavage and the particles would vary in color with thickness. Cement might contain some limestone, but not in so high a quantity as that in slide 2.

Slide 3, Figure 3

This sample was wood flour. One distinguishing feature of wood is the criss cross arrangement of fibers. Coniferous wood fibers under high magnification (500×) have a double row of round pits that are not on nonconiferous fibers.

The largest number of participants, 71 percent, identified this slide correctly. Some called it nonconiferous wood, which it was mostly; others identified it as coniferous wood, which may have been present in small quantity on some slides. Both coniferous and nonconiferous wood were also accepted as correct answers.

A few participants selected straw, presumably since wood fibers are somewhat similar in appearance; however, straw contains characteristic large bag-like cells and appears yellow in color, whereas wood does not. Inasmuch as the slides were unstained to retain the natural appearance of the particles, it was possible to note the latter difference.

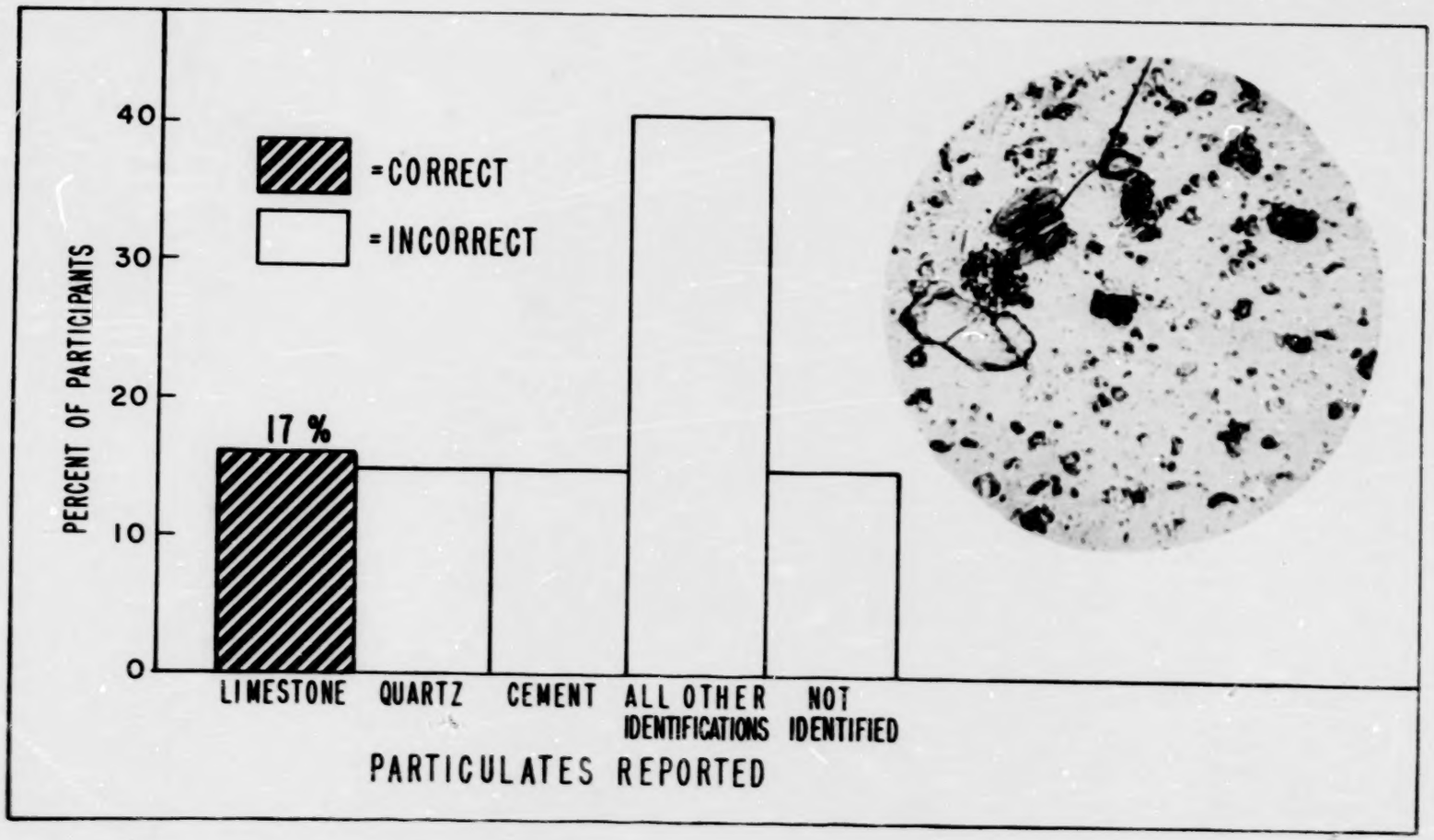

Figure 2. Responses for slide number 2.

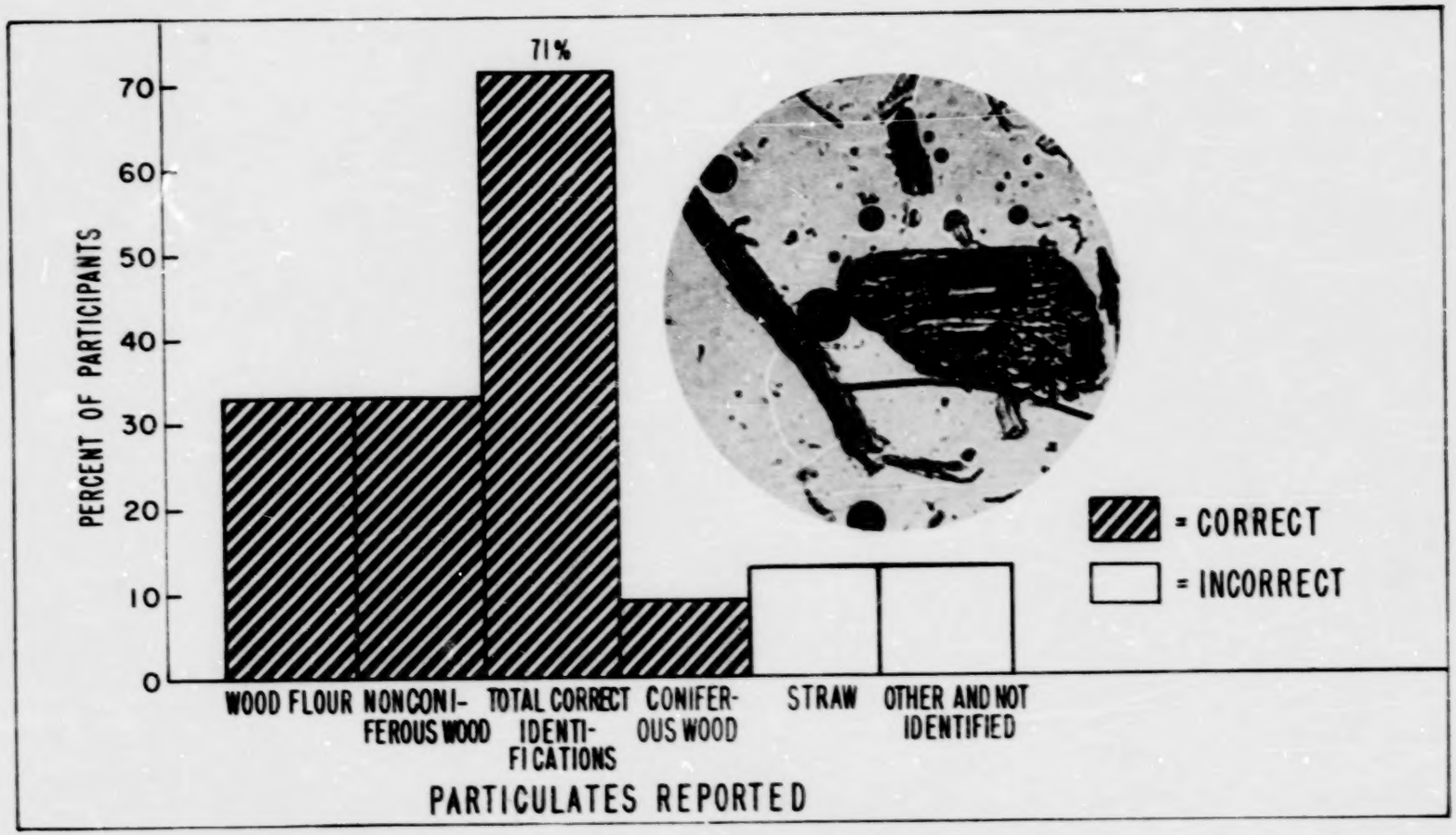

Figure 3. Responses for slide number 3.

Slide 4, Figure 4

One of the most difficult preparations to identify correctly is talc. Talc has no readily apparent crystal form, but shows a variety of subtle colors under crossed polars, and no extinction. Still, 20 percent of those responding identified it correctly.

Slide 5, Figure 5

Cement can be found to have a variety of appearances. The most common particles indicative of cement are spheres that are formed in the kiln. These spheres are usually larger and fewer than the spheres in power-plant fly ash. Other indications to look for are small botrioidal or grape-like clusters that results when particles agglomerate during roasting. Most of the particles in a cement sample will have refractive indices higher than that of the mounting medium. The amount of unreacted limestone would be very small in comparison with that found on slide 2. Fourteen percent of the participants did identify cement correctly.

Slide 6, Figure 6

Incinerator ash is best characterized by the presence of some glassy spheres, the number and size being dependent upon burning conditions; various colored and irregularly shaped particles; paper ash in varying states of ignition; and bits of wood also burnt to various degrees.

The number of correct identifications, 51 percent for this sample, was very high. Domestic-stoker ash ranked first in the number of incorrect identifications. Domestic-stoker ash, however, would contain many unburned and partially burned coal particles, which if present, would be a minor constituent of incinerator ash.

Slide 7, Figure 7

This sample, oil soot, is best characterized by many small centospheres. These particles are the results of incomplete burning of oil in oil-fired boilers or heating plants. They appear as rough black spheres with holes in their surfaces, consist of carbon, and often have a tiny droplet of oil inside. Sizes vary from source to source. Here again, the desired solid product of complete combustion would be small, glassy spheres, composed of the oxides of various metals present in the oil.

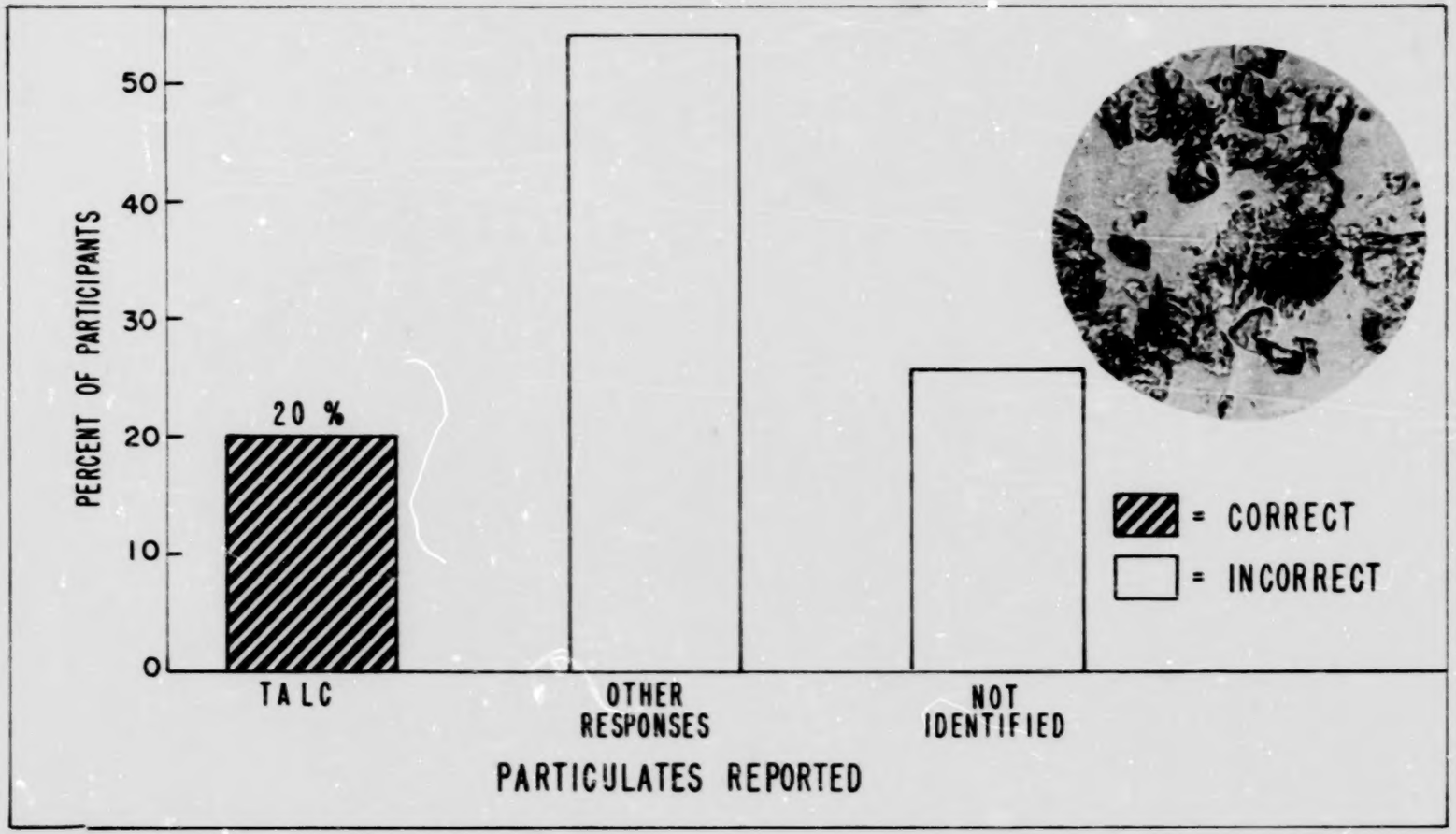

Figure 4. Responses for slide number 4.

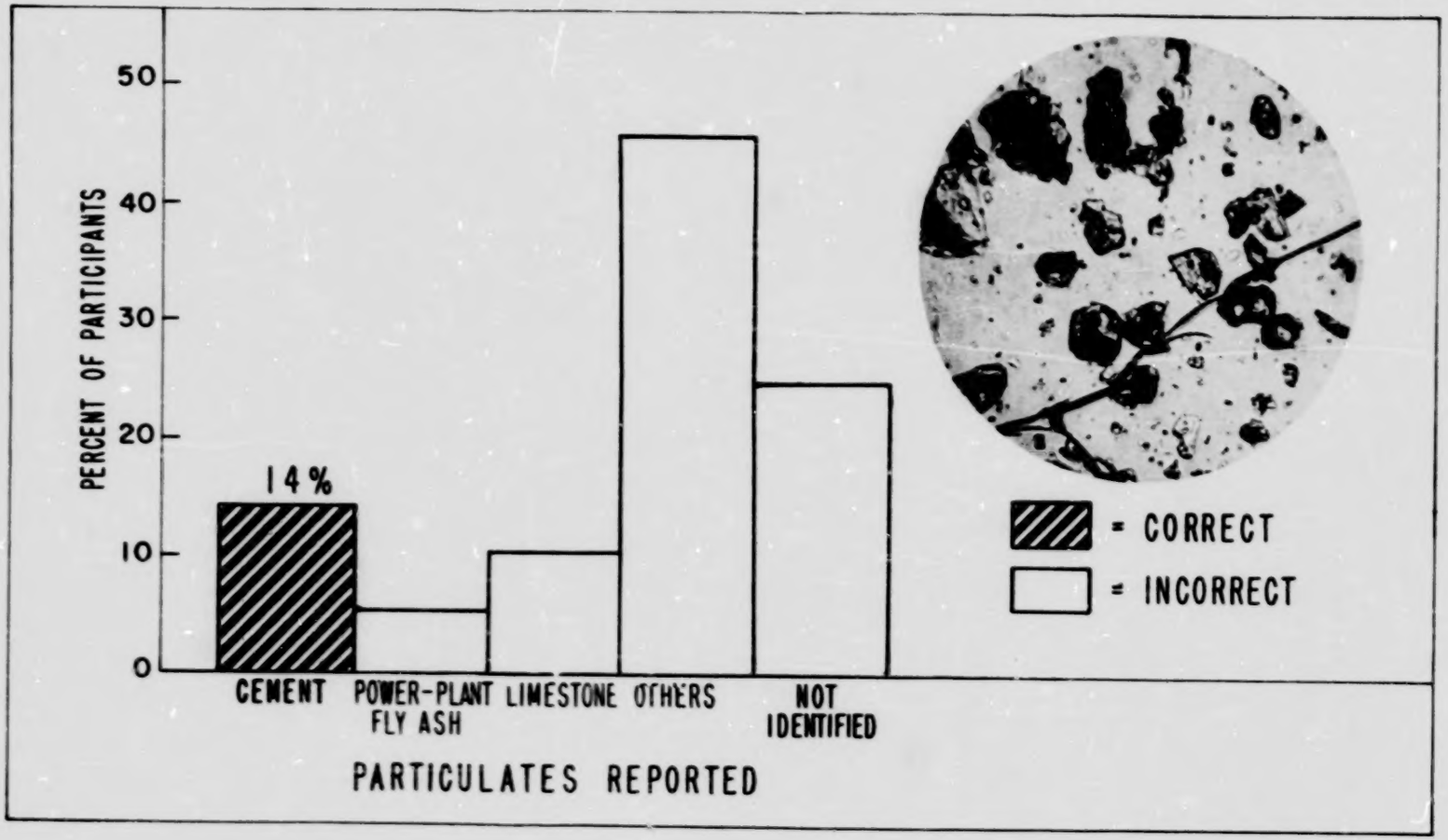

Figure 5. Responses for slide number 5.

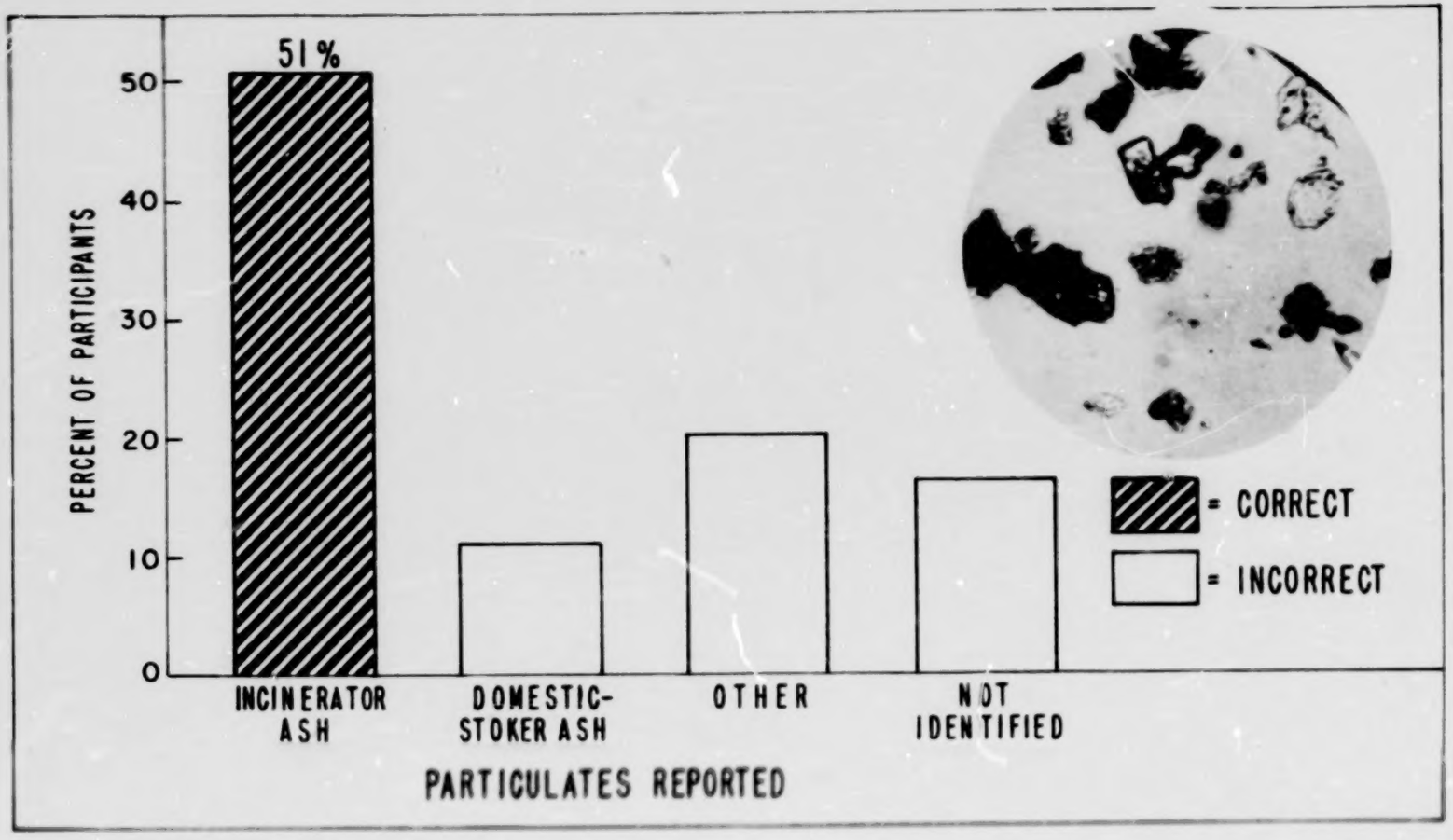

Figure 6. Responses for slide number 6.

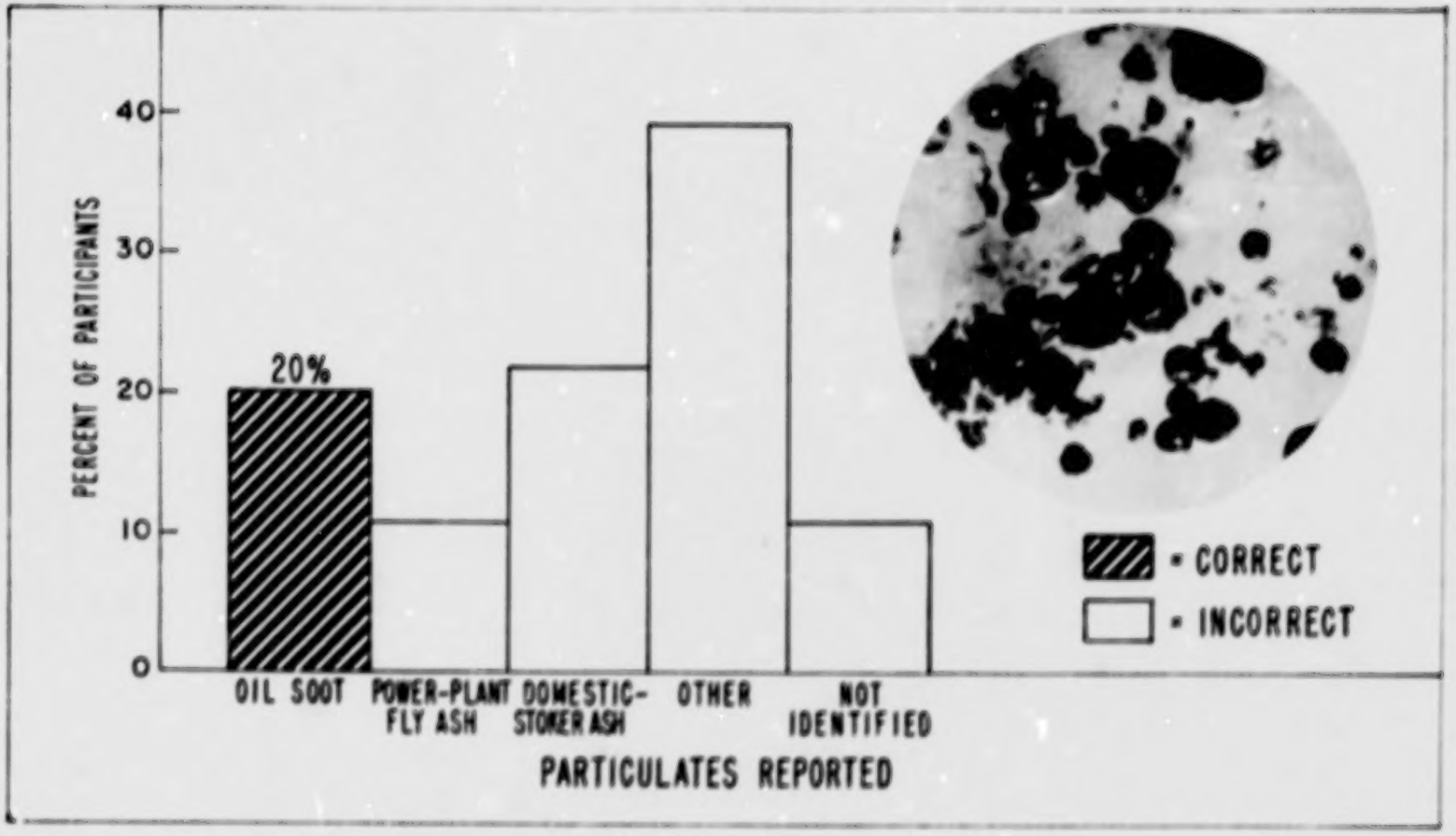

Figure 7. Responses for slide number 7.

Twenty percent identified this correctly. Domestic-stoker ash and power-plant fly ash were the predominant incorrect answers given.

Slide 8, Figure 8

This slide contained a mixture of three fibers: cotton, orlon, and mineral wool. Twenty-nine percent identified all three correctly.

Cotton fiber is rather easy to identify under the microscope because of its flat, twisted appearance. Under crossed polars the color is a light gray and white, and it is the only fiber that shows no extinction when the stage is rotated. Eighty percent identified cotton correctly.

Mineral wool is a type of industrial fiber glass very unlike ordinary fiber glass in appearance. The particles are usually shaped like spheres or elongated teardrops. They have a light brownish color and often have dark particles trapped inside. Mineral wool is also isotropic. Forty-nine percent found this particle.

Orlon is synthetic fiber best characterized by its dumbbell-shaped cross section. Forty-six percent identified orlon correctly.

Nylon and fiber glass were listed as possibilities by a large number of participants. Although nylon seems reasonable at first glance, closer inspection under the microscope shows the dumbbell-shaped cross section of orlon, whereas nylon is cylindrical. Under crossed polars, nylon shows high-order colors, and orlon shows first-order gray and white color.

Fiber glass might be mistaken for orlon. Fiber glass, however, is isotropic and would disappear under crossed polars, whereas orlon would still be visible.

Slide 9, Figure 9

This slide consisted of two major components, quartz and wood flour, and a minor component, starch, present in very small quantity. Only one participant identified all three correctly.

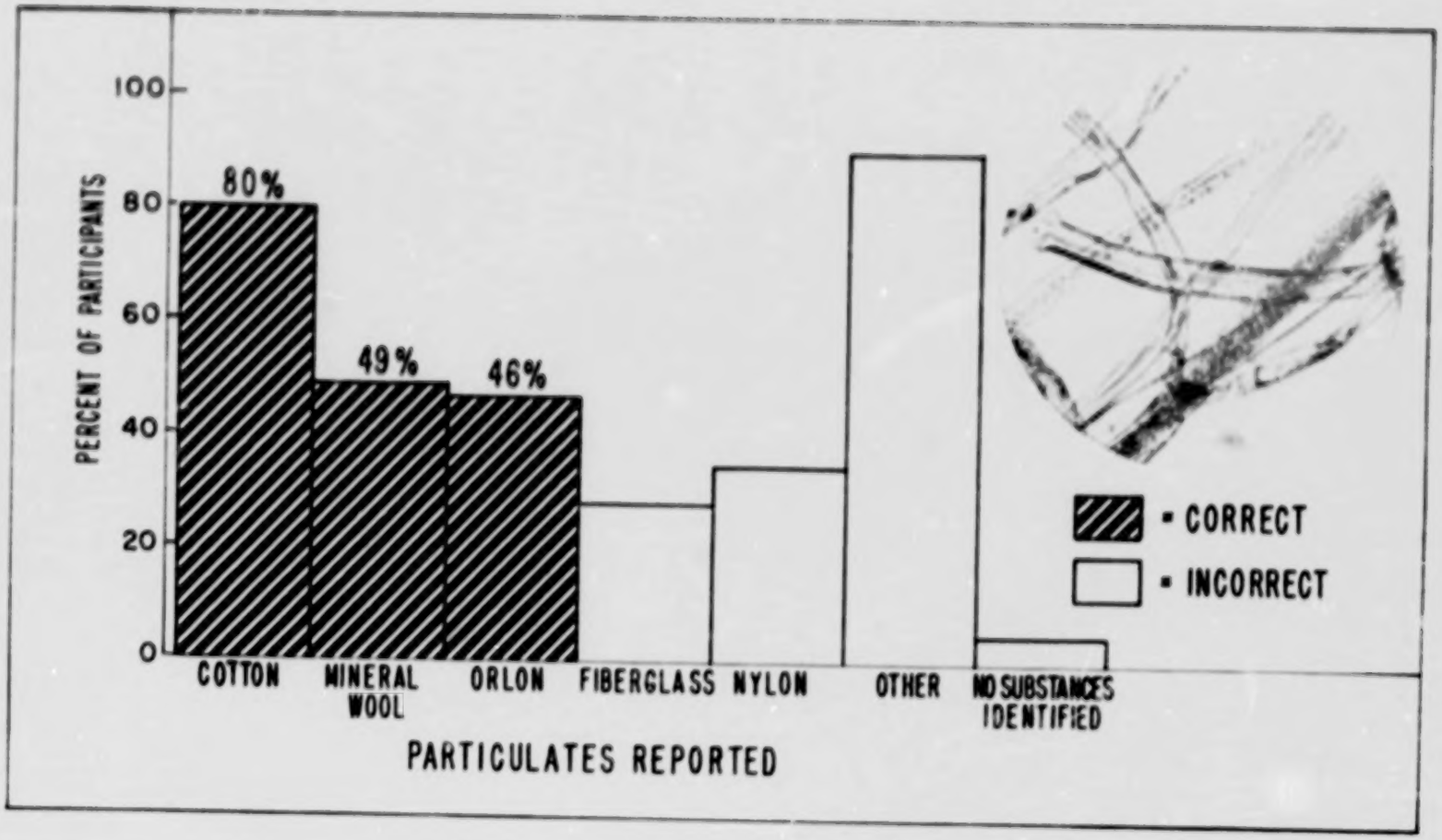

Figure 8. Responses for slide number 8.

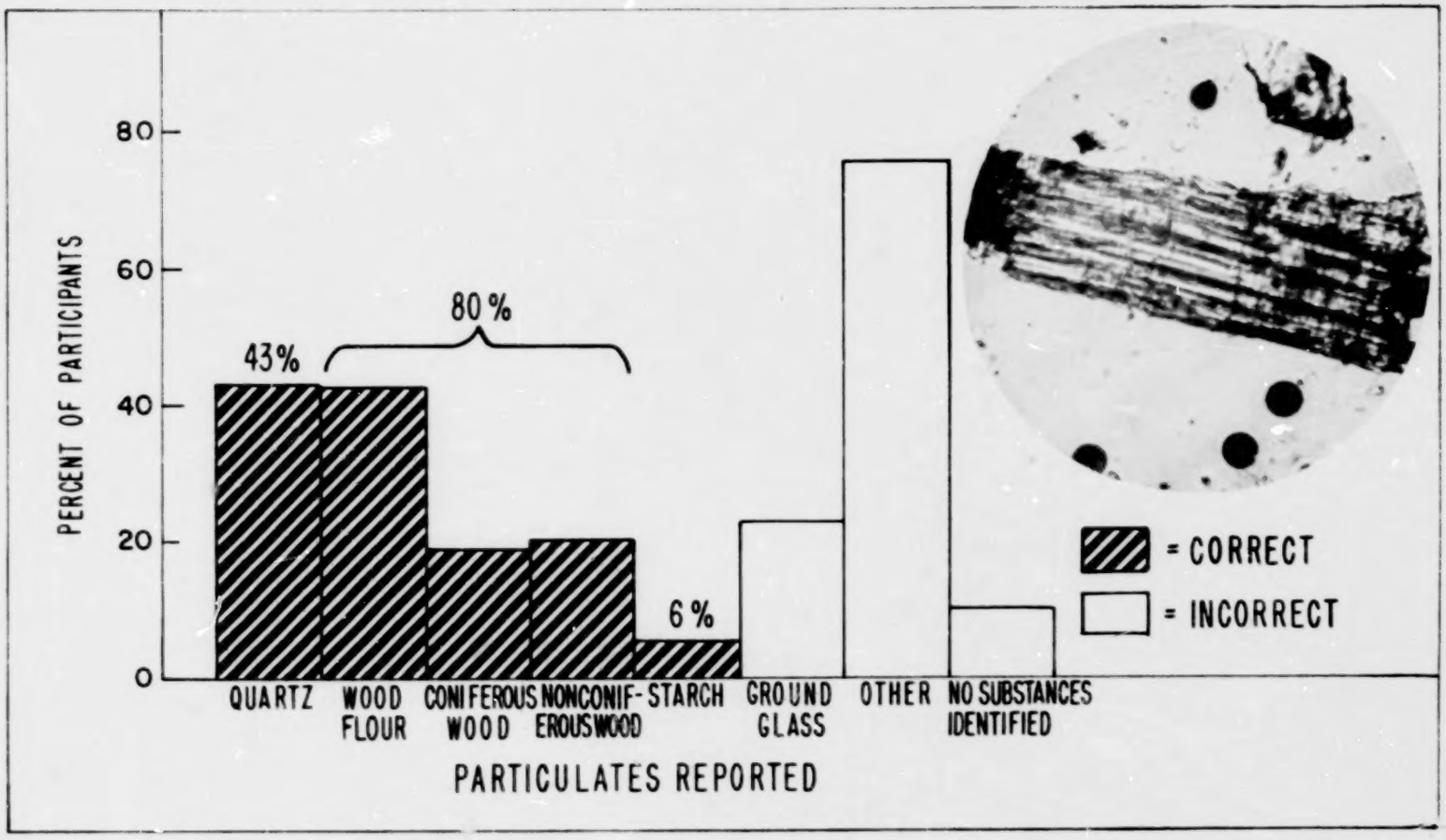

Figure 9. Responses for slide number 9.

Some of the identifying qualities of quartz are conchoidal fracture, low-order polarization colors, and refractive index lower than that of the mounting medium. Quartz can be distinguished from ground glass by crossing the polars: ground glass disappears, the quartz shows up quite vividly. Forty-three percent identified quartz correctly.

The wood-flour sample was almost completely made up of nonconiferous wood, but there could very well have been a few particles of the coniferous type on some slides. In the construction of the bar graph for this slide (Figure 9) coniferous and nonconiferous wood were also accepted as correct answers. Eighty percent identified wood in one of the three forms.

The starch, a very minor constituent on this slide, is readily identified by the dark cross or other interference figure that shows up when the grains are viewed under crossed polars. Only a very few grains were put in each preparation. Because of the small amount added, some slides may have had none or appeared to have none. In fact, only two participants found starch on slide 9.

Slide 10, Figure 10

Slide 10 was a mixture of nine components, although 10 were intended. Some of the constituents were used singly on the other slides of the series. Two participants identified correctly five out of the 10 possible components. Although these seem to be rather poor results, it should be recognized that the greater the number of the components on a slide, the greater the problems of identification. The correct and some of the incorrect identifications are listed on the bar chart (Figure 10), but only some of the incorrect identifications are discussed.

Fluorite is an isotropic, crystalline material that could be mistaken for ground glass. Ground glass, however always shows conchoidal fracture, whereas fluorite does so only in the case of some particles. Fluorite more often tends to cleave along definite patterns and the particles show definite crystalline faces. The most easily recognized is the 60 degree angle between two of the faces, which is often seen if the particle is positioned properly.

Figure 10. Responses for slide number 10.

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Incinerator ash might be given as an answer for domestic-stoker ash (see slide 6, Figure 6).

Styrofoam was listed as a component by two of the participants. Possibly some was present on a few of the slides, but a careful check by both referees of 25 of the 58 slides revealed no styrofoam at all. Some other component could be mistaken for styrofoam if one did not know what to look for. Styrofoam was either omitted from the preparation or else it dissolved in the mounting medium.

POLARIZING VERSUS NONPOLARIZING MICROSCOPE

Each participant was asked whether his microscope was equipped with a polarizer. Table 4 summarizes the results reported by those using and those not using polarizing microscopes.

Although the evidence in favor of the polarizing microscope is not overwhelming, those laboratories equipped with polarizing microscopes did better than those not so equipped. Because approximately half of the substances did not necessitate the use of a polarizing microscope for identification, the results undoubtedly are biased.

Table 4. COMPARATIVE USEFULNESS OF A POLARIZING AND NONPOLARIZING MICROSCOPE IN ESTABLISHING CORRECT IDENTITY OF PARTICULATES IN STUDY

	Laboratories with polarizing[a] microscope	Laboratories without polarizing[a] microscope
Number of laboratories	21	10
Correctly identified particles, mean	8.5	4.3
Standard deviation	3.0	3.3

[a] Four laboratories did not specify which was used.

MAGNIFICATIONS USED

Another consideration of this study was the importance of the degree of magnification and the range of magnifications employed in successful identification of slides.

In an attempt to evaluate or measure laboratory techniques, the total number of substances correctly identified by each participant was used as the criterion of participant performance. On this basis, the laboratories were divided into two approximately equal groups; the 16 laboratories in the "high group" identified from 8 to 15 of a possible 22, the laboratories in the "low group" from 0 to 7 (Table 5).

To compare the magnifications used by the low and high groups, the average magnification was computed. For example, if a participant used magnifications of 100, 400, and 700, the average magnification was 400. If a participant used only one magnification, it was taken as the average. The average magnification for the high and low groups was 257 and 259, respectively, and the standard deviations (variabilities from the averages) 200 and 180, respectively (Table 5). As can be seen, the averages are practically the same, whereas the variabilities are quite large relatively. Within the range of magnifications used by the participants, therefore, degree of magnification does not appear to be of great importance.

To investigate whether the ability to identify is increased by the use of a range of magnifications, the percent of participants using more than one magnification was computed for the high and the low correct identification groups (Table 5). The more successful group tended to use multiple magnifications (75% versus 44%). This factor, of course, would not be solely responsible for their success.

Table 5. CORRELATION BETWEEN MICROSCOPE MAGNIFICATIONS USED AND CORRECT IDENTIFICATION OF PARTICULATES

	Participants[a] identifying 0 - 7 substances correctly	Participants[a] identifying 8 - 15 substances correctly
Number of participants	16	16
Average magnification	259	257
Standard deviation	180	200
Percent using more than one magnification	44	75

[a] Three participants did not indicate magnifications used.

PARTICLE SIZE DETERMINATION

On slide 2, limestone, all participants were asked to estimate the particle size range and the average particle size. The limestone was a 325-mesh sieve sample. No data were available from the supplier on the average particle size, but, theoretically, all limestone particles should have been able to pass through a 44-micron-square sieve hole. As indicated in Table 6, the referees reported an average particle size of 4 microns and a range of 0.3 to 40 microns. Table 6 shows reasonable agreement between the results of the referees and those reported by the participants.

ESTIMATION OF PERCENT BY WEIGHT

On slides 8, 9, and 10 each participant was asked to estimate the percent by weight of each component. Table 7 shows the range of percent by weight of each component reported by the participants and the referees. No attempt was made to apply any statistical measure of comparison, because few identified correctly even a major portion of the components on each slide and some reported no weight percentage value.

In measuring and counting the particles on slides 2, 8, 9, and 10, the participants reported that the following methods were used:

Eyepiece micrometer	21
Porton disc	5
Whipple disc	4
Other	1
Not reported	4
Total....	35

Table 6. COMPARISON OF AVERAGE AND RANGE OF PARTICULATE SIZES AS DETERMINED BY PARTICIPANTS WITH REFEREE DETERMINED VALUES FOR SLIDE NUMBER 2

	Particle size, μ		
	Average	Minimum	Maximum
Participants	15	2.6	51
Referees	4	0.3	40

Table 7. ESTIMATION BY PARTICIPANTS AND REFEREES OF PERCENT BY WEIGHT OF EACH COMPONENT ON SLIDES 8, 9 AND 10

Slide	Component	Participants analysis, percent by weight	Referees' analysis, percent by weight
8	Orlon	10 to 50	25
	Cotton	<1 to 50	25
	Mineral wool	20 to 75	50
9	Wood flour	25 to 90	20
	Quartz	15 to 75	80
	Wheat starch	None found	<1
10	Gypsum	5 to 85	10
	Wool	<1 to 38	10
	Talc	20 to 25	10
	Fluorite	5 to 33	10
	Graphite	15 to 60	10
	Power-plant fly ash	0.8 to 33	10
	Metal dust	10[a]	10
	Oil soot	15[a]	10
	Styrofoam	30[b]	0
	Domestic-stoker ash	20 to 50	10

[a] Found by only one participant.

[b] Found by only two participants.

SUMMARY AND CONCLUSIONS

Of 35 participants, 16 correctly identified the particulates on slide 1, 6 on slide 2, 25 on slide 3, 7 on slide 4, 5 on slide 5, 18 on slide 6, 7 on slide 7, 61 of a possible 105 on slide 8, 43 of a possible 105 on slide 9, and 66 of a possible 315 on slide 10. Of the participants correctly identifying these particulates, those equipped with polarizing microscopes appeared to do better than those who were not so equipped. The degree and range of magnification used by the participants in identifying the particulates was also studied; and, although the degree of magnification used did not seem of great importance, the more successful group tended to use a greater range of magnification.

In estimating the particle size on slide 2, the results obtained by the participants showed reasonably good agreement with the referee results. On the other hand, the participants did very poorly in estimating the percent by weight of each component on slides 8, 9, and 10. This was, in part, because they failed to identify a major portion of the components on each slide.

In view of the lack of standard methods for identification of atmospheric particulates by using the microscope, the overall results of this study were very good. For most chemical analyses, standard methods exist; tables of data, results, photographs, and other material are available for reference. This is not the case with microscopic analysis. Most of the particulates used have not been studied to an extent that would make much data available for use in this study. Minerals and natural and synthetic fibers are the exception since considerable microscopic work has been done on them.

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APPENDICES

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APPENDIX A.

TABULATION OF RESULTS

A tabulation was made of the participants responses to each slide (Tables A-1 through A-10) and from these, a summary of the laboratories correctly identifying the particulates on each slide was compiled (Table A-11). Figure A-1 shows the distribution of the number of substances correctly identified by the participants. As a measure of how difficult each particulate was to identify, Figure A-2 compares the number of correct responses with the total possible number of correct responses for each slide.

Table A-12 lists the type of microscope, the method of measurement of particle size, and an estimation of the size of the particles on slide 2.

Tables A-13 through A-15 tabulate the percent by weight of each component on slides 8, 9, and 10 as determined by the participants, and Table A-16 tabulates the magnifications used.

Table A-1. PARTICULATE NAMED IN RESPONSE TO POWER-PLANT FLY ASH, SLIDE 1

Laboratory number	Particulate													
	Cotton	Quartz	Oil soot	Wheat starch	Power-plant fly ash	Coniferous wood	Ground glass	Potato starch	Catalyst dust	Paint spray	Ragweed pollen	Other	Not identified
02					×								
03											×		
04			×										
05					×								
06					×								
07					×								
09					×								
010					×								
011					×								
014				×									
015									×				
016					×								
017						×							
018					×								
1116													×
1225													×
1314					×								
1315													×

Table A-1. (continued)

Laboratory number	Particulate													
	Cotton	Quartz	Oil soot	Wheat starch	Power-plant fly ash	Coniferous wood	Ground glass	Potato starch	Catalyst dust	Paint spray	Ragweed pollen	Other	Not identified
1811		×											
2144					×							×	
2211										×			
2811									×				
3111			×										
3811									×				
4211	×												
4214									×				
4611			×										
5111					×								
6111										×			
7112													×
7422					×								
7813							×						
8513					×								
9223					×								
9613					×								
TOTAL	1	1	3	1	16	1	1	1	4	2	1	1	4

Table A-2. PARTICULATE NAMED IN RESPONSE TO LIMESTONE, SLIDE 2

Laboratory number	Particulate										
	Cotton	Quartz	Cement	Wheat starch	Gypsum	Fluorite	Mica	Fertilizer dust	Talc	Limestone	Not identified
02											×
03			×								
04		×					×				
05										×	
06			×								
07										×	
09				×							
010						×					
011						×					
014										×	
015									×		
016						×					
017			×								
018			×								
1116											×
1225											×
1314		×									
1315											×

Table A-2. (continued)

Laboratory number	Particulate										
	Cotton	Quartz	Cement	Wheat starch	Gypsum	Fluorite	Mica	Fertilizer dust	Talc	Limestone	Not identified
1811					×						
2144							×				
2211			×								
2811									×		
3111	×										
3811					×						
4211							×				
4214										×	
4611								×			
5111										×	
6111							×				
7112											×
7422		×									
7813		×									
8513		×									
9223										×	
9613											×
TOTAL	1	5	5	1	2	3	4	1	2	6	6

Table A-3. PARTICULATE NAMED IN RESPONSE TO WOOD FLOUR, SLIDE 3

Laboratory number	Particulate					
	Wood flour	Gypsum	Coniferous wood	Non-coniferous wood	Straw	Not identified
02	×					
03	×					
04	×					
05	×					
06	×					
07				×		
09						
010				×		
011					×	
014				×		
015				×		
016	×					
017			×			
018				×		
1116						×
1225						×
1314				×		
1315						×

Table A-3. (continued)

Laboratory number	Particulate					
	Wood flour	Gypsum	Coniferous wood	Non-coniferous wood	Straw	Not identified
1811				×		
2144	×					
2211	×					
2811	×					
3111		×				
3811				×		
4211				×		
4214			×			
4611				×		
5111	×					
6111	×					
7112					×	
7422					×	
7813				×		
8513			×			
9223					×	
9613	×					
TOTAL	12	1	3	11	4	3

Table A-4. PARTICULATE NAMED IN RESPONSE TO TALC, SLIDE 4

Laboratory number	Particulate														
	Quartz	Cement	Gypsum	Fiber glass	Metal dust	Styrofoam	Coniferous wood	Fluorite	Mica	Catalyst dust	Fertilizer dust	Talc	Limestone	Not identified
02												×		
03			×											
04		×												
05									×					
06														×
07							×							
09											×			
010						×								
011	×													
014												×		
015														×
016						×								
017									×					
018												×		
1116														×
1225														×
1314												×		
1315														×

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Table A-4. (continued)

Laboratory number	Particulate													
	Quartz	Cement	Gypsum	Fiber glass	Metal dust	Styrofoam	Coniferous wood	Fluorite	Mica	Catalyst dust	Fertilizer dust	Talc	Limestone	Not identified
1811												×		
2144			×											
2211									×					
2811														×
3111				×										
3811								×						
4211													×	
4214														×
4611														×
5111										×				
6111														×
7112	×													
7422					×									
7813												×		
8513		×												
9223												×		
9613														×
TOTAL	2	2	2	1	1	2	1	1	3	1	1	7	1	10

Table A-5. PARTICULATE NAMED IN RESPONSE TO CEMENT, SLIDE 5

Laboratory number	Particulate														
	Quartz	Cement	Incinerator ash	Power-plant fly ash	Gypsum	Metal dust	Styrofoam	Domestic-stoker ash	Ground glass	Mica	Catalyst dust	Cork dust	Limestone	Not identified
02					×									
03													×	
04						×								
05		×												
06											×			
07		×												
09												×		
010														×
011														×
014	×													
015														×
016	×													
017				×										
018								×						
1116														×
1225														×
1314													×	
1315														×

Table A-5. (continued)

Laboratory number	Particulate													
	Quartz	Cement	Incinerator ash	Power-plant fly ash	Gypsum	Metal dust	Styrofoam	Domestic-stoker ash	Ground glass	Mica	Catalyst dust	Cork dust	Limestone	Not identified
1811													×	
2144														×
2211														×
2811			×											
3111							×							
3811										×				
4211														×
4214		×												
4611								×						
5111		×												
6111									×					
7112									×					
7422				×										
7813										×				
8513					×									
9223		×												
9613			×											
TOTAL	2	5	2	2	2	1	1	2	2	2	1	1	3	9

Table A-6. PARTICULATE NAMED IN RESPONSE TO INCINERATOR ASH, SLIDE 6

Laboratory number	Particulate									
	Cotton	Cement	Incinerator ash	Nylon	Domestic-stoker ash	Ground glass	Catalyst dust	Ragweed pollen	Tobacco dust	Not identified
02					×					
03			×							
04						×				
05			×							
06			×							
07							×			
09			×							
010										×
011	×									
014			×							
015			×							
016									×	
017			×							
018			×							
1116										×
1225										×
1314			×							
1315										×

Table A-6. (continued)

Laboratory number	Particulate									
	Cotton	Cement	Incinerator ash	Nylon	Domestic-stoker ash	Ground glass	Catalyst dust	Ragweed pollen	Tobacco dust	Not identified
1811			×							
2144					×					
2211			×							
2811			×							
3111				×						
3811		×								
4211					×					
4214										×
4611			×							
5111			×							
6111										×
7112			×							
7422			×							
7813								×		
8513			×							
9223			×							
9613					×					
TOTAL	1	1	18	1	4	1	1	1	1	6

Table A-7. PARTICULATE NAMED IN RESPONSE TO OIL SOOT, SLIDE 7

Laboratory number	Particulate											
	Quartz	Oil soot	Incinerator ash	Power-plant fly ash	Gypsum	Metal dust	Graphite	Domestic-stoker ash	Paint spray	Limestone	Not identified
02			×								
03								×			
04							×				
05						×					
06						×					
07					×						
09								×			
010						×					
011								×			
014									×		
015								×			
016			×								
017								×			
018						×					
1116											×
1225											×
1314		×									
1315											×

Table A-7. (continued)

Laboratory number	Particulate										
	Quartz	Oil soot	Incinerator ash	Power-plant fly ash	Gypsum	Metal dust	Graphite	Domestic-stoker ash	Paint spray	Limestone	Not identified
1811	×							×			
2144		×									×
2211		×									
2811				×							
3111							×				
3811						×					
4211		×									
4214				×							
4611				×							
5111								×			
6111					×						
7112		×									
7422		×									
7813		×									
8513								×			
9223			×								
9613						×					
TOTAL	1	7	3	3	2	6	2	8	1	1	4

Table A-8. PARTICULATES NAMED IN RESPONSE TO COTTON, MINERAL WOOL, AND ORLON, SLIDE 8

Laboratory number	Particulate																			Number of components
	Cotton	Incinerator ash	Wood flour	Power-plant fly ash	Fiber glass	Wool	Metal dust	Mineral wool	Coniferous wood	Orlon	Nylon	Ground glass	Potato starch	Rabbit hair	Paint spray	Straw	Other	Not identified		
02	×		×		×	×										×				5
03	×				×			×		×	×									5
04	×										×			×		×				4
05	×					×		×		×					×					5
06	×				×					×							×			4
07	×				×					×										3
09	×					×		×		×							×			5
010	×							×		×							×			4
011						×											×			2
014	×							×	×		×	×								5
015	×				×			×		×	×									5
016	×							×						×						3

Table A-8. (continued)

Laboratory number	Particulate																			Number of components
	Quartz	Incinerator ash	Wood flour	Power-plant fly ash	Fiber glass	Wool	Metal dust	Mineral wool	Coniferous wood	Orlon	Nylon	Ground glass	Potato starch	Rabbit hair	Paint spray	Straw	Other	Not identified		
017	×									×	×									3
018	×							×							×			×		4
1116																		×		1
1225					×													×		2
1314	×							×		×										3
1315																		×		1
1811	×				×			×	×	×						×				6
2144	×				×			×			×							×		5
2211	×									×	×									3
2811	×							×		×	×						×			5
3111					×		×													2
3811	×									×	×									3

Table A-8. (continued)

Laboratory number	Particulate																		Number of components
	Quartz	Incinerator ash	Wood flour	Power-plant fly ash	Fiber glass	Wool	Metal dust	Mineral wool	Coniferous wood	Orlon	Nylon	Ground glass	Potato starch	Rabbit hair	Paint spray	Straw	Other	Not identified	
4211																		×	1
4214	×							×		×	×								4
4611	×	×						×			×						×		5
5111	×							×										×	3
6111	×				×	×					×				×		×		6
7112	×									×			×				×	×	5
7422	×			×															2
7813																	×		1
8513	×																×		2
9223	×							×		×									3
9613	×							×			×			×					4
TOTAL	28	1	1	1	10	5	1	17	2	16	13	1	1	3	3	3	10	8	

Table A-9. PARTICULATES NAMED IN RESPONSE TO WOOD FLOUR, QUARTZ, AND WHEAT STARCH, SLIDE 9

Laboratory number	Particulate																											
	Cotton	Quartz	Oil soot	Incinerator ash	Wheat starch	Wood flour	Power-plant fly ash	Gypsum	Fiber glass	Wool	Metal dust	Coniferous wood	Fluorite	Nylon	Graphite	Domestic-stoker ash	Ground glass	Rabbit hair	Mica	Paint spray	Nonconiferous wood	Straw	Zinc shot	Talc	Sodium chloride	Not identified	Number of components
02						×						×					×										3
03		×				×												×									3
04						×											×	×									3
05								×					×									×		×			4
06		×																×			×						3
07		×				×			×														×				4
09						×	×										×										3
010	×										×										×						3
011																	×					×					2
014		×																			×						2
015		×				×																					2
016		×				×																					2

Table A-9. (continued)

| Laboratory number | Particulate | | |

Table A-9. (continued)

Particulate

Laboratory number	Cotton	Quartz	Oil soot	Incinerator ash	Wheat starch	Wood flour	Power-plant fly ash	Gypsum	Fiber glass	Wool	Metal dust	Coniferous wood	Fluorite	Nylon	Graphite	Domestic-stoker ash	Ground glass	Rabbit hair	Mica	Paint spray	Nonconiferous wood	Straw	Zinc shot	Talc	Sodium chloride	Not identified	Number of components
4211												×														1
4214																									×		1
4611	×						×			×						×			×		×						6
5111						×																					1
6111		×				×				×	×									×							5
7112		×										×			×		×										4
7422	×			×	×												×										4
7813		×	×									×						×	×								5
8513						×																			×		3
9223		×				×																					2
9613							×														×						2
TOTAL	5	15	1	1	2	15	1	3	2	3	2	6	1	2	1	1	8	5	5	1	7	5	1	2	1	4	

Table A-10. PARTICULATES NAMED IN RESPONSE TO 10 POSSIBLE PARTICLES ON SLIDE 10

| Laboratory number | Particulate | | |

Table A-10. (continued)

Laboratory number	Particulate: Cotton	Quartz	Oil soot[a]	Incinerator ash	Wheat starch	Wood flour	Power-plant fly ash[a]	Gypsum[a]	Wool[a]	Metal dust[a]	Styrofoam[a]	Coniferous wood	Fluorite[a]	Orlon	Graphite[a]	Domestic-stoker ash[a]	Ground glass	Rabbit hair	Mica	Paint spray	Ragweed pollen	Cork dust	Nonconiferous wood	Straw	Fertilizer dust	Talc	Sodium chloride	Limestone	Not identified	Number of components
017								×	×						×															3
018		×		×	×				×																					6
1116																													×	
1225																													×	
1314				×			×		×								×													4
1315																													×	
1811	×							×	×			×	×		×										×					8
2144							×		×				×		×											×				5
2211									×						×		×		×											5
2811		×		×			×									×														4
3111																		×			×									2
3811									×										×				×	×						4

[a] Included in composition of slide.

Table A-10. (continued)

Particulate

Laboratory number	Cotton	Quartz	Oil soot[a]	Incinerator ash	Wheat starch	Wood flour	Power-plant fly ash[a]	Gypsum[a]	Wool[a]	Metal dust[a]	Styrofoam[a]	Coniferous wood	Fluorite[a]	Orlon	Graphite[a]	Domestic-stoker ash[a]	Ground glass	Rabbit hair	Mica	Paint spray	Ragweed pollen	Cork dust	Nonconiferous wood	Straw	Fertilizer dust	Talc[a]	Sodium chloride	Limestone	Not identified	Number of components
4211				×					×																					2
4214																												×		
4611																												×		
5111				×					×								×											×		4
6111								×	×	×							×			×										5
7112				×	×				×				×				×		×											6
7422				×												×														2
7813		×	×							×		×		×							×							×		7
8513																×	×													2
9233							×	×	×						×											×				6
9613				×					×	×							×													4
Total	5	3	2	15	2	1	8	6	21	3	2	3	5	1	10	5	14	2	4	2	2	2	1	2	2	4	1	6	7	

[a] Included in composition of slide.

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Table A-11. SUMMARY OF LABORATORIES CORRECTLY IDENTIFYING PARTICULATES ON EACH SLIDE

Laboratory number	Slide number										Total	
	1	2	3	4	5	6	7	8	9	10	Components identified correctly	No. slides analyzed by participant
02	1			1				1	1	2	6	5
03			1			1		3	2	2	9	5
04			1					1	1	2	5	5
05	1		1		1	1		3		3	10	6
06	1	1	1			1		2	2	3	11	7
07	1	1	1		1			2	2	4	12	7
09	1		1			1		3	1	4	11	6
010	1		1					3	1	1	7	5
011	1									1	2	2
014		1	1	1		1		2	2	3	11	7
015			1			1		3	2	2	9	5
016	1							2	2	2	7	4
017			1			1		2		3	7	4
018	1		1	1		1		2	3	1	10	7
1116											0	0
1225											0	0
1314	1		1	1		1	1	3	2	2	12	8
1315											0	0
1811			1	1		1		3	2	5	13	6
2144	1		1				1	2	1	4	10	6
2211			1			1	1	2	2	2	9	6
2811			1			1		3	2	1	8	5
3111											0	0
3811			1					2	1	1	5	4
4211			1				1		1	1	4	4
4214		1	1		×			3			6	4
4611		1	1			1		2	1		6	5

Table A-11. (continued)

Laboratory number	Slide number										Total	
	1	2	3	4	5	6	7	8	9	10	Components identified correctly	No. slides analyzed by participant
5111	1		1		1	1		2	1	1	8	7
6111			1					1	2	3	7	4
7112						1	1	2	2	2	8	5
7422	1					1	1	1	1	1	6	6
7813			1	1			1		2	2	7	5
8513	1		1			1		1	1	1	6	6
9223	1	1		1	1	1		3	2	5	15	8
9613	1		1					2	1	2	7	5
Correct identifications, total	16	6	25	7	5	18	7	61	43	66		
Possible identifications	35	35	35	35	35	35	35	105	105	315		
Percent identified	46	17	71	20	14	51	20	58	41	21		

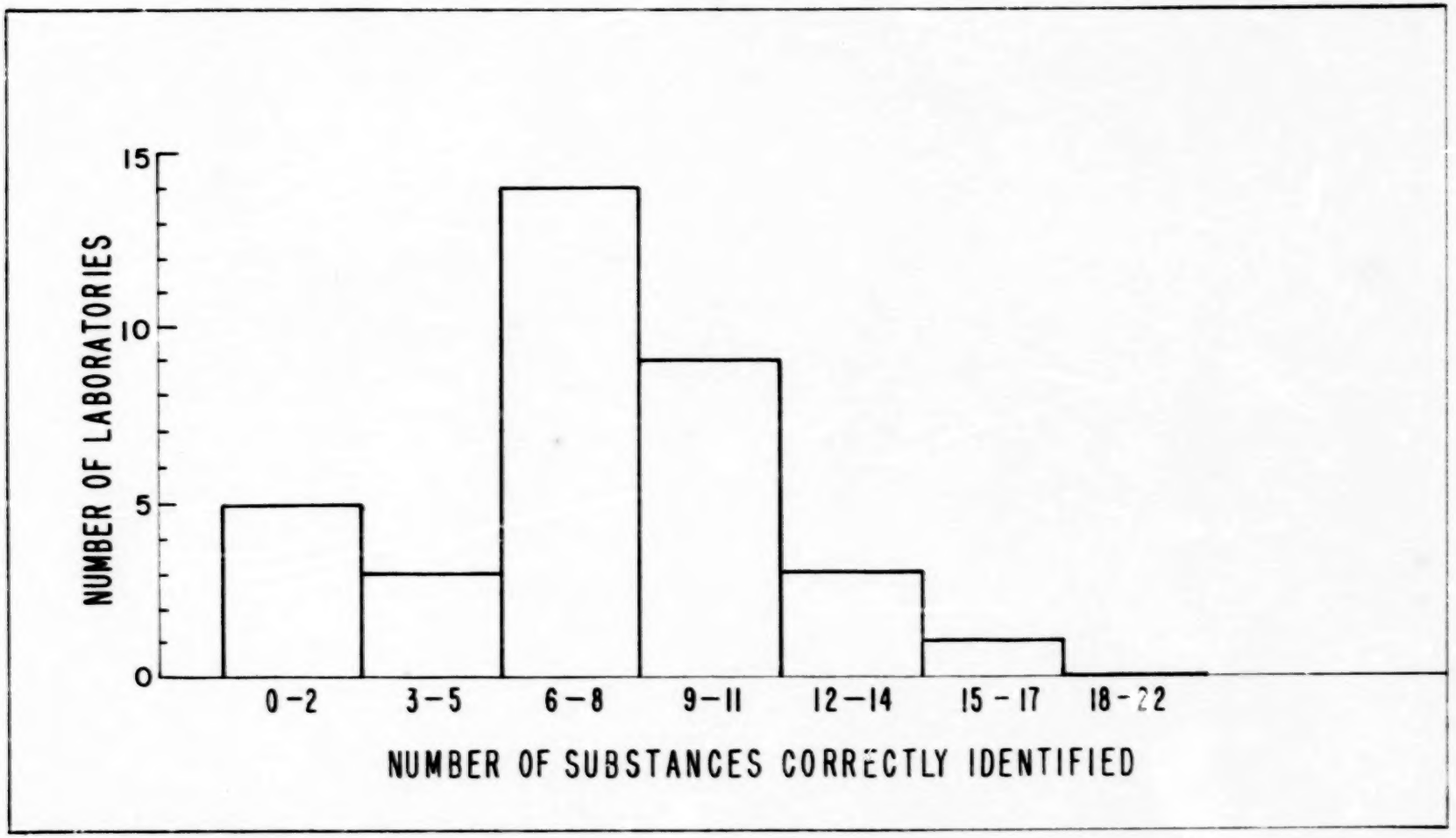

Figure A-1. Distribution of correctly identified particles.

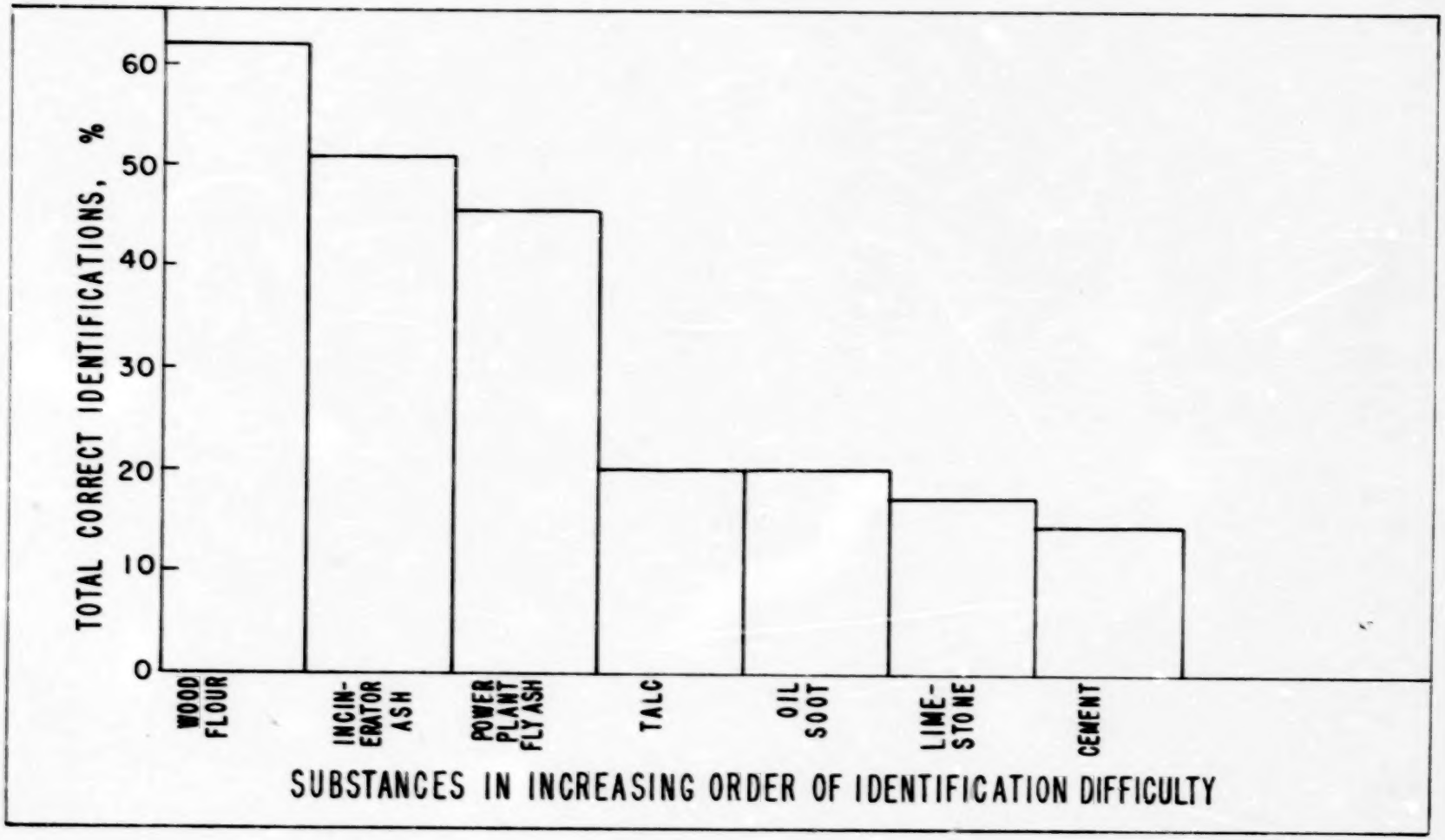

Figure A-2. Difficulty of identifying single substances on slides 1 through 7.

Table A-12. MICROSCOPE USED, METHOD OF MEASUREMENT, AND PARTICLE SIZE DETERMINED ON PARTICULATE SLI[illegible] LIMESTONE

Laboratory number	Microscope			Particle size		Method of measurement			
	Manufacturer[a]	Polarizing	Non-polarizing	Range	Average	Eyepiece micrometer	Porton disc	Whipple disc	Other
02	U	×		--	--	×			
03	B&L		×	1-60	10	×			
04	A		×	0.5-25	3.3			×	
05	U	×		0.5-60	12	×			
06	Z	×		1-20	5	×			
07	B&L	×		2-40	5	×			
09	U	×		1-40	3.9	×			
010	B&L	×		5-40	< 5	×			
011	B&L	×		--					
014	Z	×		12-43	--	×			
015	A	×		1-40	10	×			

Table A-12. (continued)

Laboratory number	Microscope			Particle size		Method of measurement			
	Manufacturer[a]	Polarizing	Non-polarizing	Range	Average	Eyepiece micrometer	Porton disc	Whipple disc	Other
016	B&L	×		1-35	8-10			×	
017	A		×	5-50	5	×			
018	A	×		0.5-52	2.9	×			
1116	B&L		×	--	--				
1225	A		×	1-30	10		×		
1314	--			10-50	25			×	
1315	CTS		×	--	1		×		
1811	Z	×		0-58	1.15	×	×		
2144	CTS	×		1-40	3.3	×			
2211	U	×		2-25	7.5	×			
2811	U	×		1-50	20	×			

Table A-12. (continued)

Laboratory number	Microscope			Particle size		Method of measurement			
	Manufacturer[a]	Polarizing	Non-polarizing	Range	Average	Micrometer	Porton disc	Whipple disc	Other
3111	--			--	--				
3811	S		×	4-48	32	×			
4211	B&L		×	1-40	17	×			
4214	Z	×		--	--				
4611	Z	×		2-86	14	×			
5111	--			--	--				
6111	Z		×	0.5-9	4.25		×		
7112	U	×		2.5-40	12.5	×			
7422	B&L	×		10-150	70	×			
7813	--			--	--				
8513	B&L		×	0.7-100	3.2		×	×	

Table A-12. (continued)

Laboratory number	Microscope			Particle size		Method of measurement			
	Manufacturer[a]	Polarizing	Non-polarizing	Range	Average	Eyepiece micrometer	Porton disc	Whipple disc	Other
9223	S	×		1-85	7.5	×			
9613	S	×		3-54	10				×

[a] U - Unitron
B&L - Bausch & Lomb
A - American Optical
Z - Zeiss
CTS - Cooke, Troughton & Simms
S - Spencer

Table A-13. ESTIMATE BY PARTICIPANTS OF THE PERCENT BY WEIGHT OF PARTICULATES ON SLIDE 8

Laboratory number	Particulate			
	Orlon	Cotton	Mineral wool	Other
02				
03	10	10	70	10
04		10		30 40 20
05	15	5	65	15
06	10	30		40 20
07	20	30		50
09	30	20	20	5 25
010	35	< 1	96	< 1
011				
014		50	30	1 15 4
015	20	20	20	30 10 ~1
016		30	60	10
017	16	12		72
018		10	75	5 10
1116				
1225				
1314				
1315				
1811				
2144			45	14 3 38

Table A-13. (continued)

Laboratory number	Particulate			
	Orlon	Cotton	Mineral wool	Other
2211	50	10		40
2811				
3111				
3811	50	25		25
4211				
4214				
4611				
5111		10	40	20 <10 20
6111				
7112				
7422		90		10
7813				
8513		5		25 5 65
9223	10	30	60	
9613				

Table A-14. ESTIMATE BY PARTICIPANTS OF THE PERCENT BY WEIGHT OF PARTICULATES ON SLIDE 9

Laboratory number	Particulate			
	Wheat starch	Wood flour	Quartz	Other
02		--		
03		39	59	2
04		55		5
05				10
				15
				30
				40
06		70	25	5
07		30	50	5
				5
				10
09		60		5
				30
010		--		
011				
014		50	50	
015		25	75	
016		50	50	
017				30
				70
018		68	15	5
				15
1116		--		
1225		--		
1314		25	75	
1315				
1811		--		
2144		75		25
2211		60	40	
2811		--		

Table A-14. (continued)

Laboratory number	Particulate			
	Wheat starch	Wood flour	Quartz	Other
3111		--		
3811		50		20 30
4211		90		10
4214		--		
4611		--		
5111		80		20
6111		--		
7112		--		
7422		--		
7813		--		
8513				15 35 50
9223		40	60	
9613		--		

Table A-15. ESTIMATE BY PARTICIPANTS OF THE PERCENT BY WEIGHT OF PARTICULATES ON SLIDE 10

Laboratory number	Particulate										
	Gypsum	Wool	Talc	Fluorite	Graphite	Power-plant fly ash	Metal dust	Oil soot	Styrofoam	Domestic-stoker ash	Other
02		--									
03		<1		33		33				33	<1
04					35			15			20 30
05					15				30	20	10 25
06		5			25	2					8 10 10 40
07		5			10	5	10				5 5 20 40
09	5	7				10				25	5 8 10 15 20
010									--		
011											
014		4	25	15							1 1 55
015											
016		2									8 10 80
017	85	38	20		42						

Table A-15. (continued)

Laboratory number	Particulate										
	Gypsum	Wool	Talc	Fluorite	Graphite	Power-plant fly ash	Metal dust	Oil soot	Styrofoam	Domestic-stoker ash	Other
018		0.9									2.4 7.0 96
1116											
1225		--									
1314		--			--	--					
1315											
1811		--	--		--	--					
2144		2.2		5	60	0.8					32
2211		10			40						10 20 20
2811		--				--					
3111											
3811		15									10 35 40
4211		5									20 75
4214											
4611											
5111		10									10 50
6111											
7112		--									
7422											

Table A-15. (continued)

Laboratory number	Particulate										
	Gypsum	Wool	Talc	Fluorite	Graphite	Power-plant fly ash	Metal dust	Oil soot	Styrofoam	Domestic-stoker ash	Other
7813											
8513										50	50
9223		35	2			30	15				3 15
9613			--								

Table A-16. MAGNIFICATIONS USED BY PARTICIPANTS

Laboratory number	Slide number									
	1	2	3	4	5	6	7	8	9	10
02	400	400	400	400	400	400	400	400	400	400
03	200	200	100	100	100	100	200	200	100	100
04	100 430	100 430 440 550	100 430	100 430	100 430	100 430	100 430	100 430	100 430	100 430
05	100 200	100 200 400	100 200	100 200 400	100 200 400	100 200	100 200 400	100 200 400	50 100 200	50 100 200 400
06	100	100	100	100	100	100 25	100 400	100 400	25 100 400	25 100
07	100	100	100	100	100	100	100	100	100	---
09	---	150 200	150 200	150 200	150 200	150 200	150 200	150 200	---	---
010	250	250	250	250	250	250	250	250	250	250
011	800 200	800 200	800 200	800 200	800 200	800 200	200 800	800 200	200 800	200 800
014	100 400 1000	100 400	100 400	100 400	100 400	100 400	100 400	100 400	100 400	100 400
015	40 100	100 40	40 970	100	100	100	100 970	100 970	100 430	100
016	200	100	100	100	100	100	430	430	860	430
017	100	100	100	100	100	100	100	100	100	100
018	100 430	430	100 430	100 430	100 430	100 430	100 430	100 430	100 430	100 430

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Table A-16. (continued)

Laboratory number	Slide number									
	1	2	3	4	5	6	7	8	9	10
1116	---	---	---	---	---	---	---	---		
1225	430	430	430	430	430	---	430	430	430	35 430
1314	200	200	200	---	---	100	200	200	200	---
1315	1200	1200	1200	1200	1200	1200	1200	1200	---	1200
1811	128	128 400	128	---	---	128	128	128	128	128
2144	225 600	225 600	225 300	225 300	225 300	225 600	225 600	225 600	225 450	225 450
2211	200 400	200 400 100	100 400	100 400	100 400	100	100 400	100 400	100 400	100 400
2811	200	200	200	---	---	---	---	---	---	---
3111	---	---	---	---	---	---	---	---	---	---
3811	100	100	100	100	100	100	100	100	100	100
4211	210	210 100	210	210	210	210	100	100	100 210	100 210
4214	125	125	125	125	125	---	125	125	---	---
4611	100 430	100 430	100 430	100 430	100 430	100 430	100 430	100 4 0	100 430	100 430
5111	100	100	100	100 450	100 450	100 450	100 450	100 450	100 450	100 450
6111	300 100	300 1000	300 100	300 100	300 100	300 100	100 300	300 100	100 300	--- ---

Table A-16. (continued)

Laboratory number	Slide number									
	1	2	3	4	5	6	7	8	9	10
7112	50 100 400	200 400	50 400	50 100 400	50 100 400	---	---	---	50 200	50 200 400 600
7422	450	450	450	450	450	---	---	---	100	--- 970
7813	---	---	---	---	---	---	---	---	---	---
8513	100 430	100 430	100 430	100 430	100 430	100 430	100	100	100 430	100 430
9223	160 360	160 360	160	160 360	160 360	160 360	160 360	160 360	160 360	160 360
9613	---	100	---	100	100	---	---	---	100	100

APPENDIX B.

ANALYTICAL REFERENCE SERVICE MEMBERSHIP

STATE AGENCIES

Alabama Water Improvement Commission
Arizona State Department of Health
Arkansas State Board of Health
California Department of Water Resources
California State Department of Public Health (Berkeley)
California State Department of Public Health (Los Angeles)
Colorado State Department of Public Health
Connecticut State Department of Health
Delaware Water Pollution Commission
Florida State Board of Health (Bureau of Laboratories, Jacksonville)
Florida State Board of Health (Division of Sanitary Engineering, Jacksonville)
Florida State Board of Health (Pensacola)
Florida State Board of Health (Winter Haven)
Hawaii State Department of Health
Idaho Department of Health
Illinois State Department of Public Health (Chicago)
Illinois State Department of Public Health (Springfield)
Illinois State Water Survey Division
Indiana State Board of Health
Kansas State Board of Health (Sanitary Engineering Laboratories)
Kentucky State Department of Health
Louisiana State Board of Health
Maryland State Department of Health
Maryland State Water Pollution Control Commission
Massachusetts Department of Public Health
Michigan State Department of Health
Michigan Water Resources Commission
Minnesota State Department of Health
Missouri Department of Public Health and Welfare
Montana State Board of Health
Nassau County Department of Health
Nebraska State Department of Health
Nevada State Department of Health (Las Vegas)
Nevada State Department of Health (Reno)
New Hampshire State Department of Health
New Hampshire Water Pollution Commission
New Jersey State Department of Health
New Mexico State Department of Public Health
New York State Conservation Department
New York State Department of Health

North Carolina Department of Water Resources
North Dakota State Department of Health
Ohio Department of Agriculture
Ohio State Department of Health
Oklahoma State Department of Health
Oregon State Board of Health
Pennsylvania Department of Health
Puerto Rico Institute of Health Laboratories
Rhode Island Department of Health
South Carolina Water Pollution Control Authority
South Dakota Department of Health
Tennessee Division of Preventable Diseases
Tennessee Stream Pollution Control Board
Texas State Department of Health
Utah State Department of Health
Vermont State Department of Health
Vermont State Department of Water Resources
Virginia State Department of Health
Virginia State Water Control Board
Washington State Department of Health
West Virginia State Water Resources Commission
Wisconsin State Board of Health

MUNICIPAL AGENCIES

Air Pollution Control District, Los Angeles, California
Alexander Orr, Jr., Water Treatment Plant, Miami, Florida
City Department of Health, New York, New York
City Department of Public Health, Pasadena, California
City Department of Water, Dayton, Ohio
City Department of Water Resources, Durham, North Carolina
City Health Department, Baltimore, Maryland
City Health Department, Beaumont, Texas
City Health Department, Houston, Texas
City Water Department, Charlotte, North Carolina
Department of Air Pollution Control, Chicago, Illinois
Department of Public Works and Utilities, Flint Water Plant
Flint, Michigan
Department of Service and Buildings, Dayton, Ohio
Department of Water and Sewers, South District Filtration Plant,
Chicago, Illinois
Erie County Laboratory, Buffalo, New York
Long Beach Water Department, Long Beach, California
Los Angeles County Flood Control District
Los Angeles Department of Public Works, Hyperion Treatment Plant
Los Angeles Department of Water and Power
Louisville Water Company, Incorporated
Metropolitan Utilities District, Omaha, Nebraska

Philadelphia Department of Public Health
Philadelphia Department of Public Health (Occupational Environment Section)
Philadelphia Suburban Water Company
Philadelphia Water Department (Belmont Laboratory)
Philadelphia Water Department (Torresdale Laboratory)
St. Louis County Water Company
St. Louis Department of Health and Hospitals
Water Works, Topeka, Kansas

FEDERAL AGENCIES

Associated Universities, Incorporated, Brookhaven National Laboratory
DHEW, PHS, Chesapeake Bay-Susquehanna River Basin Project, Annapolis, Maryland
DHEW, PHS, Great Lakes-Illinois River Basins Project, Chicago, Illinois
DHEW, PHS, Northeastern Radiological Health Laboratory, Winchester, Massachusetts
DHEW, PHS, Northeast Shellfish Sanitation Research Center, Narragansett, Rhode Island
DHEW, PHS, Off-Site Radiological Safety Program, Las Vegas, Nevada
DHEW, PHS, Water Quality Section, Division of Water Supply and Pollution Control, Cincinnati, Ohio
DHEW, PHS, Water Supply Section, Interstate Carrier Branch, Washington, D.C.
Food and Drug Administration, Division of Pharmacology, Washington, D.C.
Fourth U.S. Army Medical Laboratory, Fort Sam Houston, Texas
Government of the District of Columbia, Department of Public Health
Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee
Pearl Harbor Naval Shipyard, San Francisco, California
Sixth U.S. Army Medical Laboratory, Fort Baker, California
Tennessee Valley Authority, Wilson Dam, Alabama (Occupational Health Branch)
2793D U.S. Air Force Hospital, Regional Environmental Health Laboratory, McClellan Air Force Base, California
2794th U.S. Air Force Dispensary – Class B, Kelley AFB, Texas
U.S. Air Force Radiological Health Laboratory, Wright-Patterson Air Force Base, Ohio
U.S. Army Environmental Hygiene Agency, Maryland
U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado
U.S. Department of the Interior, Geological Survey, Columbus, Ohio
U.S. Department of the Interior, Geological Survey, Denver, Colorado
U.S. Department of the Interior, Geological Survey, Philadelphia, Pennsylvania
U.S. Department of the Interior, Geological Survey, Sacramento, California
Walter Reed Army Medical Center, Washington, D.C.

UNIVERSITIES

Case Institute of Technology, Department of Civil and Sanitary Engineering
Columbia University
University of Florida, Department of Chemistry
Georgia Institute of Technology, Department of Applied Biology
Johns Hopkins University, School of Hygiene and Public Health
University of Kansas, School of Engineering and Architecture
New Mexico State University, Department of Civil Engineering
University of North Carolina, Chapel Hill, North Carolina
University of Pittsburgh, Graduate School of Public Health
Purdue University, Department of Chemistry
Rensselaer Polytechnic Institute, Troy, New York
Rutgers - The State University
    Department of Agricultural Chemistry
    Department of Environmental Science
University of Vermont, Related Service Division
Washington State University, Division of Industrial Research

INDUSTRY

American Cyanamid Company, Bound Brook, New Jersey
Anaconda Company, Grants, New Mexico
Atlantic Refining Company, Philadelphia, Pennsylvania
Battelle Memorial Institute, Columbus, Ohio
Bethlehem Steel Company, Bethlehem, Pennsylvania
Borg-Warner Corporation, Des Plaines, Illinois
California Water Service Company, San Jose, California
Culligan, Incorporated, Northbrook, Illinois
Dearborn Chemical Company, Chicago, Illinois
Dow Chemical Company, Midland, Michigan
E.I. du Pont de Nemours and Co., Aiken, South Carolina
El Paso Natural Gas Products Company, Conda, Idaho
Eimith Laboratories, Incorporated, Brooklyn, New York
Fairbanks, Morse, and Company, Research Center, Beloit, Wisconsin
Food Machinery and Chemical Corporation, Fountain, Idaho
General Electric Company, Louisville, Kentucky
Goodyear Atomic Corporation, Piketon, Ohio
HALL Laboratories Division, Calgon Corporation, Pittsburgh,
    Pennsylvania
Hazleton Nuclear Science Corporation, Palo Alto, California
Industrial Chemicals, Incorporated, South Bend, Indiana
Intex, Incorporated, Cambridge, Massachusetts
Kennecott Copper Corporation, Salt Lake City, Utah
Maryland Cooperative Milk Producers, Inc., Baltimore, Maryland
Midwest Research Institute, Kansas City, Missouri
Monte Vista Company, Anaheim, California
Monsanto Chemical Company, St. Louis, Missouri

NALCO Chemical Company, Chicago, Illinois
Pacific Gas and Electric Company, Emeryville, California
Pacific Gas and Electric Company, San Francisco, California
Pan American World Airways, Patrick Air Force Base, Florida
Pomeroy and Associates, Pasadena, California
Radiation Detection Company, Mountain View, California
Reynolds Electrical and Engineering Company, Las Vegas, Nevada
Ray F. Weston, Incorporated, Newtown Square, Pennsylvania
Sandia Corporation, Sandia Base, Albuquerque, New Mexico
Shell Chemical Company, New York, New York
Southern Testing and Research Laboratories, Wilson, North Carolina
Tracerlab, Incorporated, Richmond, California
U.S. Industrial Chemicals Company, Tuscola, Illinois
Water Service Laboratories, Incorporated, New York, New York

FOREIGN

British Coke Research Association, Chesterfield, Derbyshire, England
Central Electricity Research Laboratories, Leatherhead, Surrey, England
Comissao Inter-Municipal de Controle da Poluicao das Aguas E Do Ar, Sao Paulo, Brazil
Department of Health Services and Hospital Insurance, Vancouver, B.C., Canada
Department of Municipal Laboratories, Hamilton, Ontario, Canada
Department of National Health and Welfare, Ottawa, Ontario, Canada
Department of National Health and Welfare, Occupational Health Division, Ottawa, Ontario, Canada
Department of National Health and Welfare, Vancouver, B.C., Canada
Instituto Nacional de Obras Sanitarias, Caracas, Venezuela
Metropolitan Corporation of Winnipeg, Manitoba, Canada
Metropolitan Water, Sewerage, and Drainage Board, Sydney, Australia
Ministere de la Sante, Montreal, Quebec, Canada
National University of Colombia, Bogota, Colombia, South America
Permutit Company, Limited, London, England
Scientific Research Council, Kingston, Jamaica, West Indies
Taiwan Institute of Environmental Sanitation, PHS, Taiwan
- Pingtung Air Pollution Laboratory
- Pingtung Organic Waste Laboratory
- Taichung Water Laboratory
- Tainan Water Laboratory
- Taipei Milk Laboratory
- Taipei Radiological Health Laboratory
- Taipei Water Laboratory
- Taitung Water Laboratory

United Kingdom Atomic Energy Authority, Didcot, Berks, England
University of Beograd, Civil Engineering Faculty, Beograd, Yugoslavia
University of Leeds, Houldsworth School of Applied Science, Leeds, England
Water Research Association, Marlow, Buckinghamshire, England